Appl. No. 10/009,910
Amdt. Dated September 22, 2004
Reply to Office Action of June 24, 2004

Attorney Docket No. 81839.0107
Customer No. 26021

REMARKS/ARGUMENTS

Claims 1-10 are pending in the Application. Claims 1-10 are submitted to clearly distinguish patentably over the prior art in their present form, for the reasons set forth below. No new matter is involved.

In Paragraph 2 on page 2 of the Office Action, claim 9 is rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement. According to this Paragraph "Claim 9 recites, 'in which oxygen precipitation nuclei of 1×10^9'". It is further stated therein "There is no support for oxygen precipitation nuclei. The instant specification merely teaches a BMD density of 1×10^9, note page 13 of the specification".

Such statements indicate a misunderstanding of the present invention. Claim 9 defines a silicon wafer having an N-region over an entire plane, with carbon doping. By doping the crystal with carbon, the formation of oxygen precipitation nuclei can be accelerated by heating treatment at a low temperature of from 600 to 1000 °C. This is described at lines 16-23 of page 9, at the last line of page 9 through line 4 of page 10, and at lines 3-8 of page 16 of the specification. More specifically, a wafer having an N-region over an entire plane, with carbon doping, is subjected to heat treatment at a low temperature of from 600 to 1000 °C, and thereby the oxygen precipitation nuclei can be formed. Then, by subjecting the wafer to heat treatment of, for example, 800°C/4Hr + 1000°C/16Hr., to grow oxygen precipitates, BMD having the density of 1×10^9 number/cm^3 or more can be obtained in the wafer. In this connection, see line 21 of page 17 through line 2 of page 18, and lines 10-17 of page 23, of the specification.

Namely, the BMD density is the density of internal micro defects due to oxide precipitates, and the density of BMD is the density of oxide precipitates that oxygen precipitation nuclei grow. In this connection, see line 25 of page 5 through line 10 of

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page 6 of the specification. Therefore, it is natural that there is oxygen precipitation nuclei of 1×10^9 number/cm³ or more formed by heating treatment at a low temperature of from 600 to 1000 °C because the density of BMD that oxygen precipitation nuclei grow is 1×10^9 number/cm³ or more in the wafer, in the present invention.

Therefore, the density of oxygen precipitation nuclei as set forth in claim 9 of the present application is supported in the specification and is the effect of carbon doping. Consequently, claim 9 is submitted to comply with the written description requirement, and withdrawal of the rejection of the claim under 35 U.S.C. § 112, first paragraph, is respectfully requested in view of this explanation.

Beginning with paragraph 4 on page 3 of the Office Action, the claims are rejected on various combinations of Iida, et al. Fujikawa, Tamatsuta et al., Hourai, et al., and Asayama, et al. These rejections are respectfully traversed.

The Examiner's response to Applicants' arguments in the Amendment of April 12, 2004 are set forth beginning with Paragraph 11 at the bottom of page 12 of the Office Action. In this connection, Applicants have noted the comments at lines 5-19 of page 14 of the Office Action as well as the comments at lines 4-9 of page 15 of the Office Action. Applicants' initial impression was that this discussion was in response to Applicants' arguments set forth beginning in the last paragraph of page 7 and continuing through the first paragraph on page 9 of the Amendment of April 12, 2004. However, in reading this over, Applicants note that there appears to be a misunderstanding of both the present invention and what is represented by the cited references. More particularly, and in accordance with the present invention, by doping the crystal with carbon, the pulling rate to obtain the N-region is improved faster irrespective of no change of temperature gradient. The speeding up for the N-region cannot be easily derived from Iida et al., Fujikawa, Hourai et al. and Asayama et al.

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The Office Action states beginning at line 5 of page 14 thereof, "The combination of Iida et al. and Fujikawa teaches doping a single crystal with carbon during pulling and controlling the pulling rate and temperature gradient to form an N-region. The increase in pulling rate would have been expected based on the teachings of Iida et al. because the pulling rate is varied between 1.0 mm/min and 0.4 mm/min to determine the optimum pulling rate for forming an N-region, note Example 1". As further stated on page 14, "Applicants' argument that a person of ordinary skill in the art cannot derive the present invention from Iida in combination with Fujikawa and it is impossible to pullig (sic) a silicon single crystal at a rate greater than the rate of pulling a single crystal with no carbon doping is not persuasive because it is viewed as mere attorney argument, which lacks evidence. Iida et al. teaches varying pulling speed between 1.0 mm/min and 0.4 mm/min to determine the optimum pulling speed for pulling an N-region, note col 14, ln 20-30. The pulling speed taught by applicant is 0.63-0.65 mm/min (page 8 of the remarks), which is within the pulling speed range taught by Iida et al; therefore the optimum pulling speed could be determined by routine experimentation".

As further stated at lines 4-9 of page 15 of the Office Action, "Applicants' argument that the pulling rate to obtain the N-region is 0.52-0.54 mm/min is noted but is not found persuasive. Iida et al teaches the pulling rate is 0.52-0.54 mm/min for a specific embodiment and temperature gradient. Iida et al is not limited to this pulling speed, as suggested by applicants. Iida et al also teaches varying pulling speed between 1.0-0.4 mm/min and splitting the grown crystal longitudinally to observe variations in crystal defects to determine the optimum pulling speed for forming an N-region, note Example 1".

These recitations in the Office Action seem to suggest that in the case of carbon doping, experimental changing of the pulling rate can be carried out, and the optimum pulling rate for forming an N-region should be found by splitting the

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grown crystal longitudinally, as in the manner of Iida et al. However, any assumption that the experimental changing of pulling rate is carried out in the case of carbon doping is erroneous.

It is said that the distribution of the crystal defect in the silicon single crystal is determined by the parameter of V/G, which is the ratio of the pulling rate V and the temperature gradient G (see page 4, last paragraph in the specification, lines 50-60 of column 1 of Iida et al., the claims in Hourai et al., and so forth). The pulling rate V can be controlled to change freely in the range, for example, of 0.4-1.0 mm/min, as described in Iida et al., also. However, the temperature gradient G depends on the hot zone structure of the CZ furnace, and is determined by the structure of the furnace used. Therefore, in order for the gradient G to be changed, it is necessary to change the internal structure of the furnace before growing the crystal, and it is almost impossible to control changing of the temperature gradient G during growing of the crystal (see line 41 of column 9 through line 15 of column 10 of Iida, line 59 – last line of column 1 and lines 44-58 of column 4 of Hourai et al).

Therefore, experimentation by controlling pulling rate V to change, for example, 0.4-1.0 mm/min and observation of the distribution of the crystal defect by splitting the grown crystal longitudinally, may be carried out at only one time with no change of the crystal diameter because the same structures of the furnace have the same temperature gradient G. Because the same internal structure of the CZ furnace can fix the temperature gradient G, the distribution of the crystal defect is determined only by the pulling rate V. Conversely, with no change of the temperature gradient G, the distribution of the defect is determined only by the pulling rate V, and therefore further experimentation of change of the pulling rate as in Iida et al. is meaningless.

Certainly, one of ordinary skill in the art can understand that temperature gradient doesn't change, even though the crystal is doped with very little carbon in

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pulling. Namely, in doping the crystal with carbon, a person of ordinary skill in the art would have no idea of how to carry out the experimentation to change the pulling rate as in Iida et al., irrespective of there being no change of the temperature gradient G.

Moreover, the experimentation that the pulling rate V is controlled to change, such as for example, 0.4-1.0 mm/min, and the distribution of the crystal defect, is observed by splitting the grown crystal longitudinally. This cannot be done by routine experimentation as suggested in the Office Action. The single crystal ingot grown by the CZ method is not sliced longitudinally to obtain circular silicon single crystal wafers as the products. Therefore, no products can be obtained from the whole single crystal ingot by splitting the single crystal ingot longitudinally. Experimental destruction of an entire very expensive silicon single crystal ingot should not be done without good reason.

On the other hand, doping of the crystal with carbon, as in the case of the present invention, does not change the temperature gradient G. In that instance, the V/G value can be controlled only by the pulling rate V. Therefore, one of ordinary skill in the art would naturally think that a crystal having the desired defect distribution (here, N-region) can be obtained by the pulling rate V as known in the prior art.

However, and in accordance with the present invention, it is demonstrated that the pulling rate V for the crystal to be N-region can be improved faster than in the case of the prior art by carbon doping, with no change of temperature gradient G. The V/G value for the N-region came to shift by carbon doping in that the pulling rate V for the N-region is changed irrespective of any change of temperature gradient G. The present inventors learned this for the first time, and it would not have been obvious for one of ordinary skill in the art to find this out. Preferably, and as described above, the distribution of the crystal defect is determined by the

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pulling rate V with no change of temperature gradient G because the distribution of the crystal defect is determined by the V/G value. The present invention defies the conventional wisdom of those skilled in the art that the crystal has a N-region by the same value of the pulling rate V with the prior art if the temperature gradient G does not change. Therefore the knowledge in accordance with the present invention would not be predictable for one of ordinary skill in the art.

It is again emphasized that the pulling rate for the N-region can be improved faster irrespective of there being no change of temperature gradient in the crystal, by doping the crystal with carbon in the case of the present invention. Namely, the V/G value for the N-region shifted (see the description in the last paragraph of page 7 through the first paragraph of page 9 of Applicants' prior Amendment).

As previously described, the understanding in accordance with the present invention that the pulling rate for the N-region can be improved faster by doping with carbon means that the V/G value for the N-region shifts by doping with carbon. The temperature gradient doesn't change by doping with carbon, and the pulling rate for the N-region shifts faster irrespective of any change of G, and therefore the V/G value itself to control changes.

For example, and as described at page 15 of the specification, the pulling rate for the N-region with no carbon doping is 0.52-0.54 mm/min. Therefore, and in accordance with the method of Iida et al., the pulling rate is adequately controlled to be in the range of such pulling rate, and the crystal of the N-region is pulled with the predetermined V/G value. V/G is made to become such value by controlling the pulling rate adequately.

However, and in accordance with the understanding provided by the present invention, the pulling rate for the N-region shifts to become 0.63-0.65 mm/min by doping with carbon. Therefore, the V/G value to control is changed (here, 0.183 − 0.177 mm³/K·min). It is impossible to control the value to the shifted range because

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the shift of the V/G value by the carbon doping is unknown in Iida et al., Hourai et al., or the other cited references. Because the dopant dependence of the V/G value is not known in such cited references, it is evident that the pulling rate is absolutely intended to control to the same pulling rate V with no carbon doping, and it is impossible to control the shifted pulling rate or the V/G value as in the case of the present invention. This is because changing V with no change of G results in a higher V/G value rather than the desired V/G value. In Iida et al. or in Hourai et al., making the pulling rate V high with no change of temperature gradient G results, not in an N-region over the entire plane but rather a V-rich region (an infrared scattering defect developing region). This is generated because the V/G value becomes higher (see figures 3, 4 and 10 of Iida et al. and figures 2-5 of Hourai et al.).

Again, and by way of clarification of the misunderstandings evidenced by the statements referred to above in the Office Action, the present invention makes possible the growing of crystal at a high speed as a result of the shift of the V/G value for the N-region by carbon doping. This is neither shown nor suggested by any of the cited references or by any of the attempted combinations thereof.

Therefore, claims 1-10 are submitted to clearly distinguish patentably over the prior art, for the reasons discussed above. Reconsideration and allowance are respectfully requested.

If for any reason the Examiner finds the application other than in condition for allowance, the Examiner is requested to call the undersigned attorney at the Los Angeles, California telephone number (213) 337-6846 to discuss the steps necessary for placing the application in condition for allowance.

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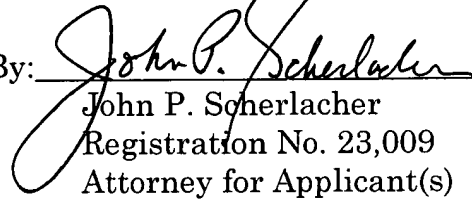Reply to Office Action of June 24, 2004

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If there are any fees due in connection with the filing of this response, please charge the fees to our Deposit Account No. 50-1314.

Respectfully submitted,

HOGAN & HARTSON L.L.P.

Date: September 22, 2004

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